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SPATIAL DISTRIBUTION OF SURFACE ALTERATION AND GROUND TEMPERATURE AT WAIRAKEI THERMAL (GEYSER) VALLEY, NEW ZEALAND

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ABSTRACT

A survey of thermal activity, shallow (15 cm deep) temperatures, and surface alteration at Wairakei (Geyser Valley), made in September 1989, shows that activity there extends over an area of about 7500 m^2 and now consists entirely of steaming ground (>80°C), warm ground (40°-80°C), fumaroles and mud pools. Features which prior to 1960 discharged alkali-chloride water are now either extinct or else replaced by fumaroles. However, two new fumaroles have appeared in recent years, and the occurrence of silica sinter, including geyserite, records the locations of the extinct alkali-chloride features. Steam-condensate-produced alteration comprises a subzone of kaolinite + alunite ± hematite ± silica polymorphs, which is associated with presently steaming ground, and a kaolinite + smectite ± hematite ± alunite ± cristobalite ± tridymite ± amorphous silica subzone. The latter occurs in areas of fossil steaming ground, surrounding geyserite deposits and associated with mud pools.

INTRODUCTION

Geyser Valley, now called Wairakei Thermal Valley, is located on the NE edge of the Wairakei geothermal field which lies 8 km north of Lake Taupo, North Island, New Zealand (Fig. 1). Topographically, the Wairakei Stream is the only significant water course traversing the valley (from NW to SE). The stream bed is eroded to about 370-380 m a.s.l., while both sides of the stream rise steeply up to 430-440 m a.s.l.

Prior to the exploitation of the Wairakei Geothermal Field, Geyser Valley was the site of vigorously flowing alkali-chloride springs that deposited silica sinter, and 22 geysers which played at regular intervals (Grange, 1937; Glover, 1977). Changes were noted, however, after exploration and drilling started in 1954. Water levels in the boiling springs decreased, and geyser activity diminished. Continuous withdrawal of fluid from the borefield caused the extinction of the alkali-chloride discharges and replaced them with steaming ground, fumarolic activity and acid alteration. Between about 1962 and 1968, there were at least 11 thermal and chemical surveys of the valley, but none for the next 20 years (Glover, 1977).

A reconnaissance survey was made in the valley during September 1989 to delineate present-day thermal activity and the distribution of surface alteration. This work was undertaken to determine the extent of changes that have taken place since features discharging alkali-chloride water became extinct; as such, this survey will also provide a base for subsequent evaluations of thermal activity in the valley.

GEOLOGICAL SETTING OF WAIRAKEI VALLEY

The Valley is situated within the north-east resistivity boundary of the Wairakei field (Risk et al., 1984). Rocks exposed in the area consist of Taupo Pumice Alluvium, Taupo Ignimbrite, and 22,700-year-old Wairakei Breccia. These are all dominantly vesicular, rhyolitic in composition, and contain phenocrysts, in varying proportions, of quartz, plagioclase (andesine), rare hypersthene, hornblende, traces of augite and magnetite. Rock fragments are common, and comprise obsidian, other rhyolites and rare andesite, but the main feature of the lithology of the deposits is their pumiceous nature.

Several normal, north-east-striking faults, extending from the bore field, cut the area (Grindley, 1965), but the axis of the valley itself is oriented towards the north west, suggesting that there is a significant structural control in this direction also. However, faults clearly provide channels for ascending geothermal fluids.

METHODOLOGY

Active and extinct thermal features were mapped (Figure 1). A map by Gregg and Laing (1951) of the Geyser Valley, showing the thermal features existing in 1951, facilitated the mapping of these features as most still exist, although changed. Some features, however, have been obscured by fallen trees, excavations or slumps. Detailed descriptions and photographs of the individual features are given in Cong (1989) and Vargas (1989).

A total of 332 soil temperature measurements were made, using a dial type maximum thermometer, to delineate the approximate extent of thermal ground (Figure 2). These measurements were carried out by pushing the thermometer into the ground to about 15 cm depth and recording the temperature. The measurements were taken in a grid pattern at approximately 15 m spacing.

Eighty-seven samples of altered rock and silica sinter from the Wairakei Valley were collected. Forty-three clay-bearing and seven sinter samples were analysed by X-ray diffraction.

SURFACE ACTIVITY

Active thermal features

Active thermal features in the valley consist of steaming and warm ground, mud pools and fumaroles (Fig. 1). These occur on both sides of the valley, but activity is more vigorous on the northern bank. The extent of the active thermal area was mapped from the ground temperature measurements and type of vegetaaon cover (Figure 2). There are two main areas of activity at different elevations. The northerly thermal area, at the higher elevation (about 435 m), has an axis aligned in a north-easterly direction, whereas the other, at an elevation of 375 to 390 m, has an east to east-north-west lineation.

Steaming ground

This is characterised by surface temperatures that exceed 80°C at 15 cm depth, with either bare ground or moss and lichen cover and stunted manuka at its periphery. Most of the steaming ground occurs on the north bank of Wairakei Valley on the terrace at an elevation of about 395 m and on the hill above (Figure 2).

Warm ground

This occurs in areas where ground temperatures at 15 cm depth are between 25°C and 80°C (Figure 2), and vegetation typically comprises manuka, moss, and low pines.

Steam vents and fumaroles

Most of the steam vents and fumaroles occur at the sites of former chloride springs; steam discharge is typically diffuse. Two new steam vents with vigorous steam discharge (Figure 1) have appeared in recent years.

Mud pools

Mud pools occur within an area of steaming ground at the edge of the north bank terrace and on the saddle, at about 435 m elevation, of the hill north of the Wairakei Stream (Figure 1).

Extinct thermal features

The sites of alkali-chloride springs and geysers are marked by extensive silica sinter deposits (Figure 3). Most sinter deposits are buff to, cream coloured and massive, with some micro terrace structures preserved that indicate former fluid flow directions. An area in the western part of the valley (Figure 1) comprises kaolin clays and hematite; this was formerly steaming or warm ground that has since cooled (Figure 2).

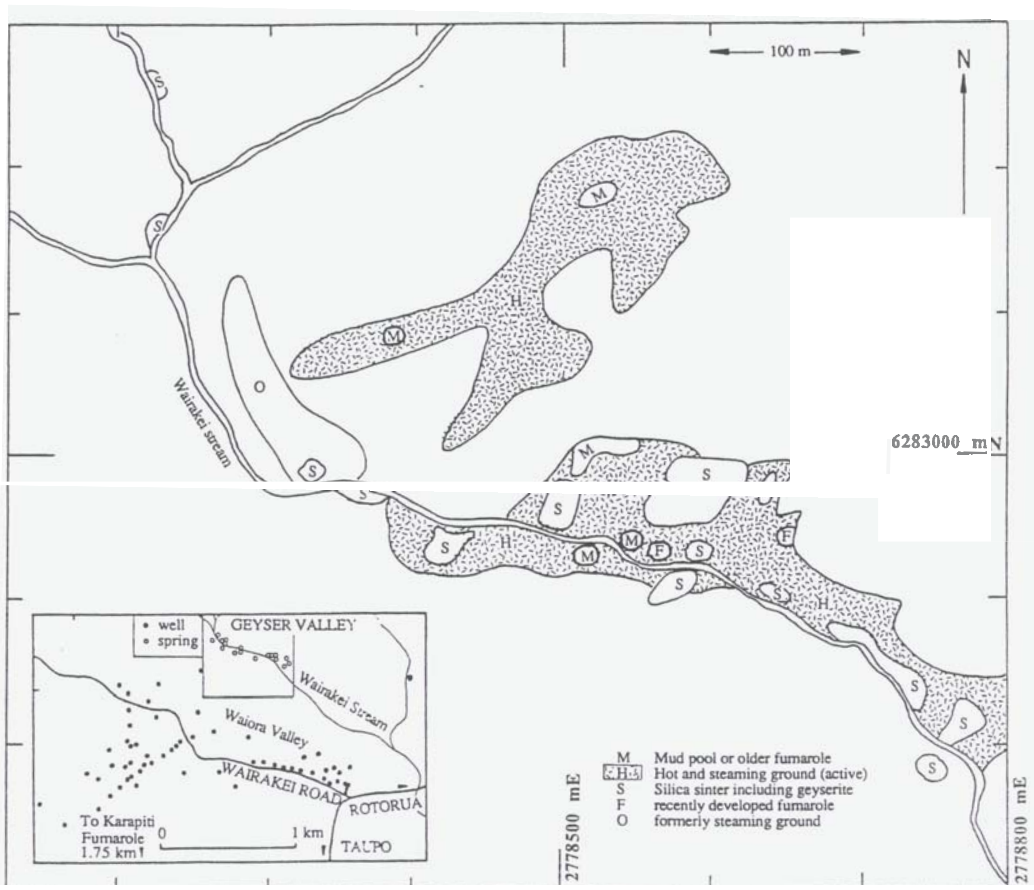

Figure 1. Map of Wairakei (Geyser) Valley showing the dismbution of the present-day thermal activity and silica sinter formed from sprngs and geysers active in 1950.

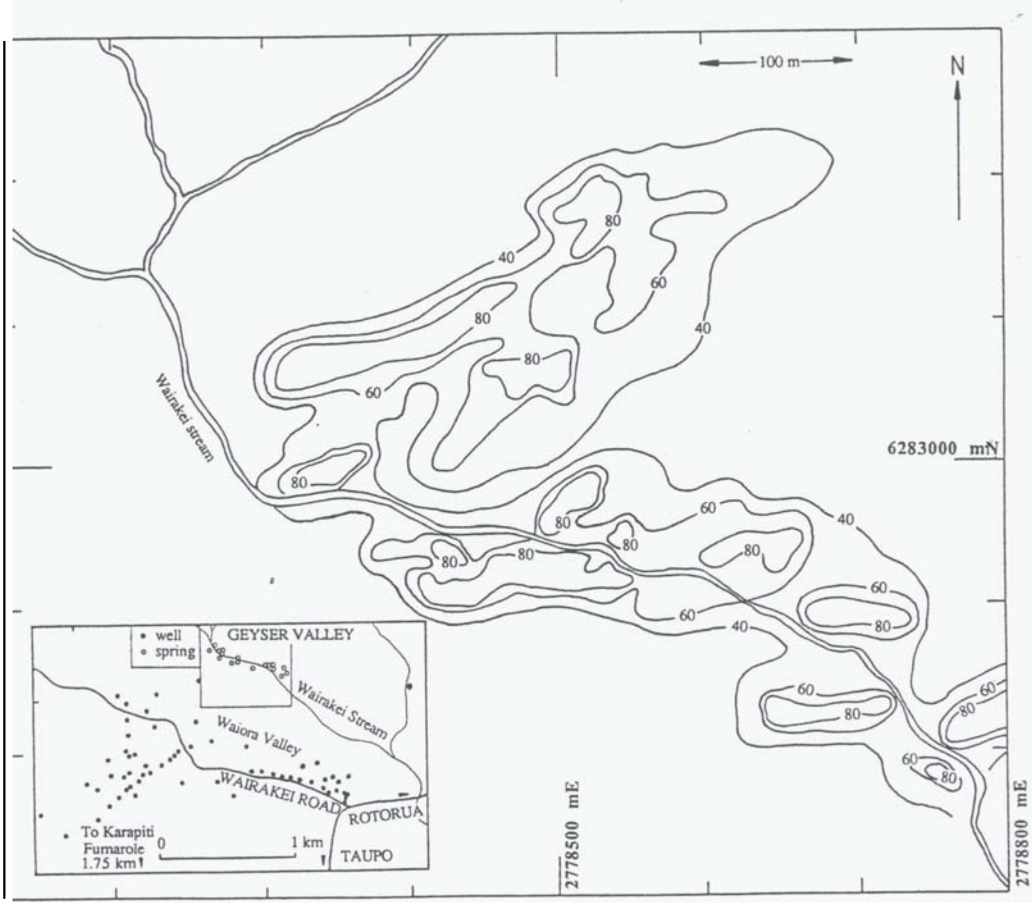

Figure 2. Isotherms at 150 cm depth in Wairakei Valley based on 332 measurements taken on a 15 m grid. Temperatures are in °C.

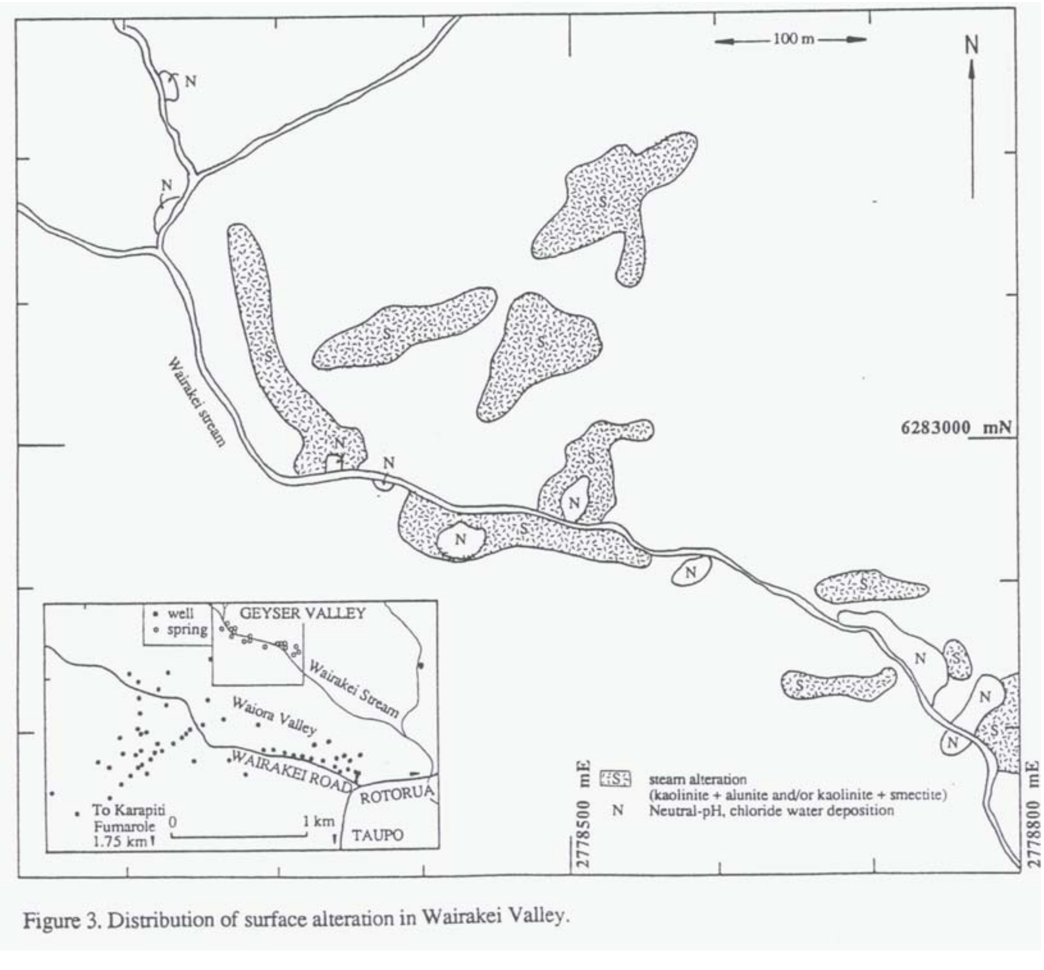

Figure 3. Distribution of surface alteration in Wairakei Valley.

TEMPERATURE SURVEY

The results of the 332 temperature measurements made at 15 cm depth are shown in Figure 2. The highest temperatures, 100°C, occur mostly in areas of active steaming ground; active mudpools are mostly between 22°C and 40°C, but some that were dry at the time of the survey reached 90°C. Several places of clay alteration and silica sinter are now at about ambient (12°C) temperatures. The temperature survey shows that the area of ground above 60°C, however, largely coincides with the distribution of present-day surface activity, but the 40°C isotherm encompasses warm places outside the area of present steam discharge.

HYDROTHERMAL ALTERATION

Figure 3 shows the surface distribution of hydrothermally altered materials within Wairakei Valley. This is based on identifications made by X-ray diffraction. Intensities of alteration range from incipient replacement of glass to complete destruction of all primary constituents and textural features. The most unstable component present in the fresh rocks is glass, followed, in order of increasing stability, by hypersthene, augite, hornblende, plagioclase, and quartz.

Steam-produced alteration

This is indicated by the Occurrence of widespread kaolinite, which is the most abundant mineral present in areas of steaming ground; it shows different degrees of crystallinity (up to very highly crystallised). Montmorillonite (smectite) is present at the margins of present and former activity, where it forms from the neutralisation by host rocks of migrating acid condensate waters. It also occurs in some of the mudpools and in areas of steaming ground surrounding dead geysers. Alunite, and natroalunite, occur mainly in areas of steaming ground in the western part of the valley, where they commonly coexist with kaolinite. Minor amounts of other sulphates present in the steam-altered zone are jarosite and gypsum, and native sulphur also occurs.

The type of silica present include tridymite, low-cristobalite (XRD peak at 4.06 Å), amorphous opaline silica and quartz. These form mostly from the destruction and replacement of volcanic glass, although some mdymite and quartz is probably of primary origin. Hematite occurs in patches, but pyrite is very rare. Cracks in the ground are occasionally coated by grey material, possibly of organic derivation.

The steam-produced alteration can be subdivided into two subzones:

(a) A kaolinite-alunite subzone which, together with hematite and silica minerals, is most common in areas of active steaming ground;

(b) kaolinite-smectite subzone. This may also contain hematite, alunite and silica phases. It is generally present in areas of fossil steaming ground, surrounds geyserite deposits and is associated with mud pools.

Water-produced alteration

Silica sinter, including geyserite, is present mainly along low terraces of the Wairakei Stream. Clearly, it deposited from features discharging alkali chloride water (Glover, 1977). Some features surrounded by silica sinter now discharge steam, but others, mainly in the eastern section of the valley, are quite dead.

Steam-overprint alteration

Cessation of flow from alkali-chloride springs and geysers and the change of some to steam discharges allows an opportunity to see if any alteration overprinting has had time to take place. This has apparently occurred at some features but not others. Geyserite surrounding the Great Wairakei Geyser, for example, now contains kaolinite that has probably formed since it ceased to discharge alkali-chloride water in 1968. Elsewhere, the sinter is simply cracking and fracturing.

DISCUSSION

The changes in thermal activity that have occurred in Wairakei Valley since 1951 result from exploitation of the Wairakei Geothermal Field. Some changes were noted as early as 1957. These, and changes that occurred from then until 1968, have been described in detail by Glover (1977). Heat flow studies also showed a decline in heat input into Wairakei Valley from 52 MW in 1951 to 5 MW in 1979 (Allis, 1981); this largely reflects the extinction of alkali-chloride springs as the area affected by steaming and warm ground in the valley does not seem to have changed greatly except for the cooling of a western section (Figure 1). Some features formerly discharging hot water are now steam vents but others are dead; two new fumaroles have appeared since earlier surveys were made.

The thermal areas in Wairakei Valley, as shown by both ground temperatures and the distribution of surface alteration, follows two trends:

(a) one in a north-north-east direction concordant with a north-east-trending lineament and marked by hot to warm altered ground with mud pools and collapse pits at the saddle at an elevation of 435 m, and

(b) a narrow, mainly easterly-trending steam-heated zone, with extinct alkali-chloride springs and silica sinter deposits.

Two types of alteration occur: active and extinct. The alteration still forming is steam produced and of two types. One is very to moderately intense, and characterised by the assemblage kaolinite ± silica polymorphs ± hematite ± alunite. In the field it is very soft and puggy, with hematite stains. The other type is of weaker intensity, and comprises an assemblage of cristobalite + amorphous silica ± kaolinite ± traces of smectite. The extinct alteration includes silica sinter close to Wairakei stream, and patches of kaolinite/hematite located in the western section of the field.

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